The distribution of the endangered Black Grass-dart Butterfly, *Ocybadistes knightorum* (Lepidoptera: Hesperiidae)

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ABSTRACT

The Black Grass-dart Butterfly, *Ocybadistes knightorum* is endemic to the New South Wales north coast. The species has a very restricted distribution and a high degree of specificity, feeding as a larva only on Floyd's Grass, *Alexfloydia repens*. Both species and host-plant are listed as endangered in the State, partly because they were known from only a few localities at the time of listing. We have mapped the entire known habitat of the butterfly at a very fine scale using a hand-held GPS. A total of 293 patches of potential *A. repens* habitat were mapped and surveyed for *O. knightorum*. The butterflies were confirmed to occupy 155 of these patches, including all of the large patches (those ^{3}0.1 ha). The mapped habitat was found to be highly protected in reserves and environmental protection zones. However, despite the huge increase in known localities and their high degree of protection, serious threats remain that are operating wholly or partly independent of tenure. These include sea-level rise, weed invasion and anthropogenic disturbance. Further assessment of threats is needed to reappraise the conservation status of the species adequately.

Key words: butterfly conservation, threatened Lepidoptera, endangered species, Australian butterflies, *Ocybadistes, Ocybadistes knightorum.*

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Introduction

The north-east region of New South Wales (NSW) has been identified as being an area of "exceptional species richness" for butterflies in Australia owing to the overlap of Torresian (northern) and Bassian (southern) species and the occurrence of a number of subtropical endemic species (Braby 2000). The Black Grass-dart Butterfly, *Ocybadistes knightorum* (Fig. 1) is a subtropical endemic of the NSW north coast. It was first collected near Sawtell and described only relatively recently (Lambkin and Donaldson 1994). *O. knightorum* is a small skipper, with a wingspan of less than 2 cm (Braby 2000).

O. knightorum is typical of the Australian members of the sub-family Hesperiinae. It occurs along the Australian east coast, has a specific habitat preference and forms localised and sedentary colonies (Braby 2000). However it is one of only four endemic species in the Hesperiinae, which contains 37 species known to occur in Australia (Braby 2000). Furthermore, the other five described

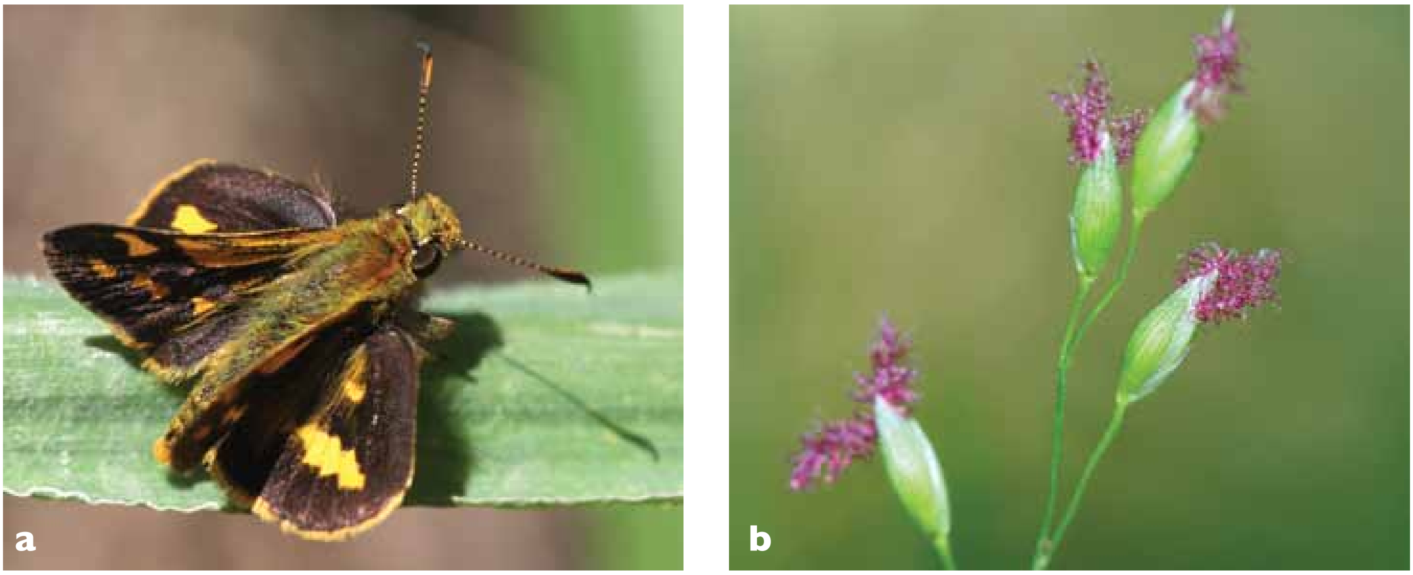

Figure 1. (a) The Black Grass-dart Butterfly, *Ocybadistes knightorum* and (b) Floyd's Grass, *Alexfloydia repens.* Photos by Paul Sheringham.

species within the genus *Ocybadistes* that are found in Australia are common and occur widely (Braby 2000). In contrast with these broadly distributed congeners, *O. knightorum* has an extremely restricted distribution (Lambkin and Donaldson 1994).

Atkins (1996) first reported that a grass, superficially resembling Couch, *Sporobolus virginicus* and believed to be Matgrass, *Hemarthria uncinata*, was the sole or at least the principal larval food plant of *O. knightorum* (Atkins 1996, citing TA Lambkin, pers. comm.). This may have been in error as Sands (1997) could identify only Floyd's Grass, *Alexfloydia repens* (Fig. 1) as a food plant. All subsequent observations have supported the identification of *A. repens* as a food plant, and to date no others have been verified.

A. repens was first found by local botanist Alex Floyd on 12 October 1987 south of Sawtell near Pine Creek in what was to become Bongil Bongil National Park (A. Floyd pers. comm. 2010). Simon (1992) later recorded *A. repens* from two additional localities: Cordwells Creek (a tributary of Boambee Creek) and Pine Creek. *O. knightorum* was later observed at both these localities by Sands (1997). He observed the butterfly ovipositing on *A. repens* and considered that the butterfly was almost certainly monophagous and therefore entirely dependent on *A. repens* (Sands 1997). *A. repens* occurs within low-lying swamp forest dominated by Swamp Oak, *Casuarina glauca* and Broadleaved Paperback, *Melaleuca quinquenervia* (Fig. 2).

O. knightorum appears to be a multi-voltine species with several overlapping generations each year (Atkins 1996; Sands and New 2002). The eggs are laid on the underside near the tip of the leaf of *A. repens*, with the first instar emerging after 12-14 days (Atkins 1996). The pupal stage normally lasts 14-16 days (Atkins 1996). The winter brood, however, is slow to develop and eggs laid in April/May do not produce adults until September/October (Atkins 1996; D. Sands pers. comm. 2010). In captivity, adults live for 10 – 16 days, with 16 days estimated to be near their maximum adult lifespan in the wild (D. Sands pers. comm. 2010, from unpublished data). The flight period extends from late August to early May (M. Andren pers. obs. 2011).

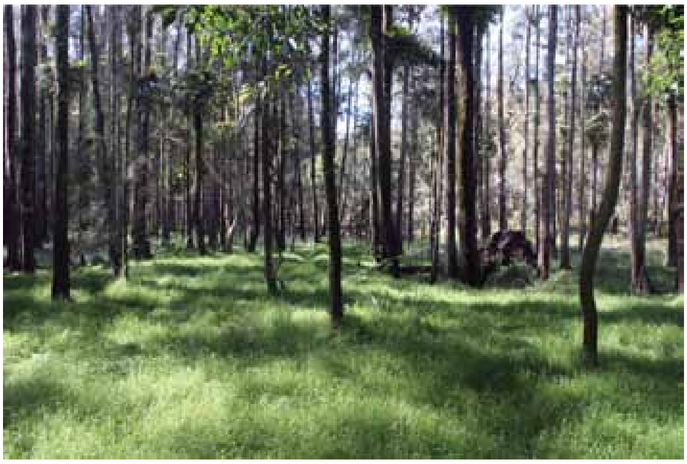

Figure 2. *A. repens* in typical Swamp Oak habitat. Photo, P. Sheringham.

In 2001, *A. repens* was listed by the NSW Scientific Committee as an endangered species under the NSW *Threatened Species Act 1995*. *O. knightorum* was subsequently, in 2002, also listed as an endangered species. The Committee found that the butterfly was restricted to a few small discrete patches of *A. repens* that were all threatened by weed invasion (NSW Scientific Committee 2002). The view of the Committee was that the species;

> *"…is likely to become extinct in nature in New South Wales unless the circumstances and factors threatening its survival or evolutionary development cease to operate" (NSW Scientific Committee 2002).*

The geographically limited occurrence of *O. knightorum*, its high specificity regarding its food plant and its long adult flight period presented a rare opportunity to survey and map the entire distribution of the species at a very fine scale. The survey and mapping is a first step in reassessing the conservation status of the species; to begin this reassessment, we also examine its current reservation status.

Methods

The study initially focussed on the known range of *O. knightorum*, centred on the Sawtell area of the NSW north coast (Fig. 3). Extensive consultation was undertaken with local butterfly experts, botanists, rangers, bush regenerators and others to collate existing knowledge of the known *A. repens* sites. The known sites were then used in conjunction with satellite images, digital aerial photography, LiDAR (Light Detection And Ranging), vegetation mapping and geology mapping to identify additional sites of potentially suitable habitat. In the Sawtell area, most of the potentially suitable sites were surveyed.

Likely areas of potential habitat north and south of Sawtell were also investigated, from Woolgoolga in the north to Scotts Head in the south. There were insufficient resources to survey this entire area to the same degree as that achieved for Sawtell, so only the most likely potential habitat was targeted. The study area originally included only the Sawtell area plus adjacent catchments. However, it was extended by over 40 km south to Scotts Head after the discovery of the butterfly in that locality during the survey.

All patches of *A. repens* were considered to be likely habitat of *O. knightorum*. *A. repens* typically grows in a clumped habit and patches usually have a distinct boundary that can be delineated. This enabled the manual mapping of each patch by walking the patch boundary with a hand-held GPS. The boundaries were captured with a HP iPAQ handheld PC with a SirfStar III compact flash GPS card and using ESRI Arcpad 7. With good satellite coverage, the GPS used was accurate to 1 m. All patches found that were 1 m^2 or greater were mapped. It was not considered logistically feasible to map patches below this size, plus tiny patches were considered unlikely to be important habitat for the butterfly. Fortunately, due to its habit of growing in large clumps, the vast majority

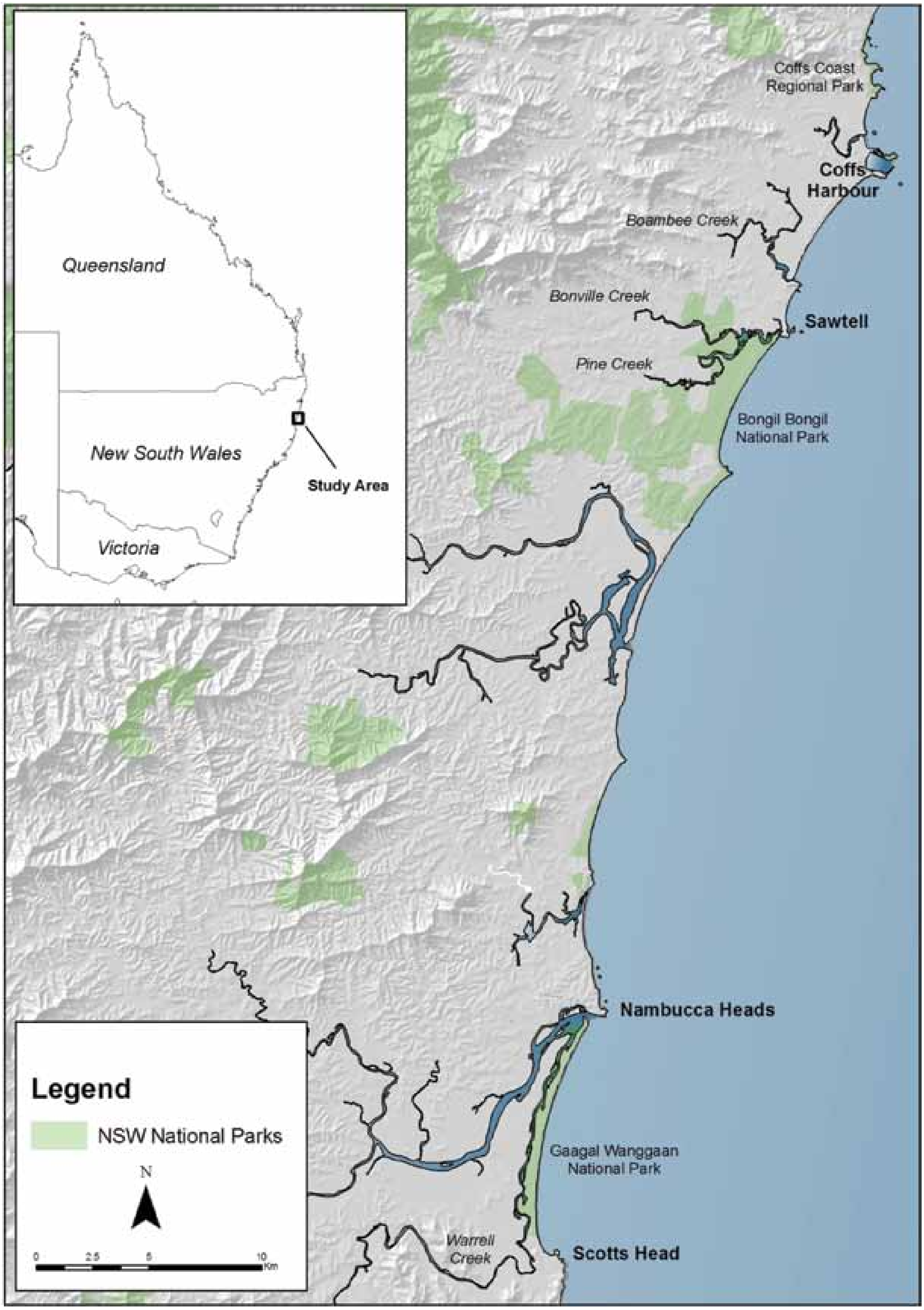
Coffs Coast Regional Park
Coffs Harbour
Boambee Creek
Bonville Creek
Sawtell
Pine Creek
Bongil Bongil National Park
Queensland
New South Wales
Victoria
Study Area
Nambucca Heads
Legend
NSW National Parks
N
0
2.5
5
10
Km
Gaagal Wanggaan National Park
Warrell Creek
Scotts Head

Figure 3. Study area along the NSW north coast, showing NPWS reserves.

of the grass occurred in patches greater than 1 m^2. The mapping was carried out between October 2008 and March 2011. A minor amount of mapping on inaccessible private property had to be extrapolated from nearby occurrences of *A. repens*.

Mapping was undertaken during peak flying time for the butterfly (on sunny days between 10 am and 2 pm) and each patch of *A. repens* was thoroughly searched for adult butterflies. It was noted during preliminary field work that adult *O. knightorum* were often observed up to about

20 m away from patches of *A. repens*. All *O. knightorum* observed greater than 20 m from *A. repens* were therefore recorded to gain an indication of the use of the more distant matrix by adult butterflies.

Results

A total of 32.5 ha of potential *O. knightorum* habitat was mapped in 293 separate patches (Fig. 4).

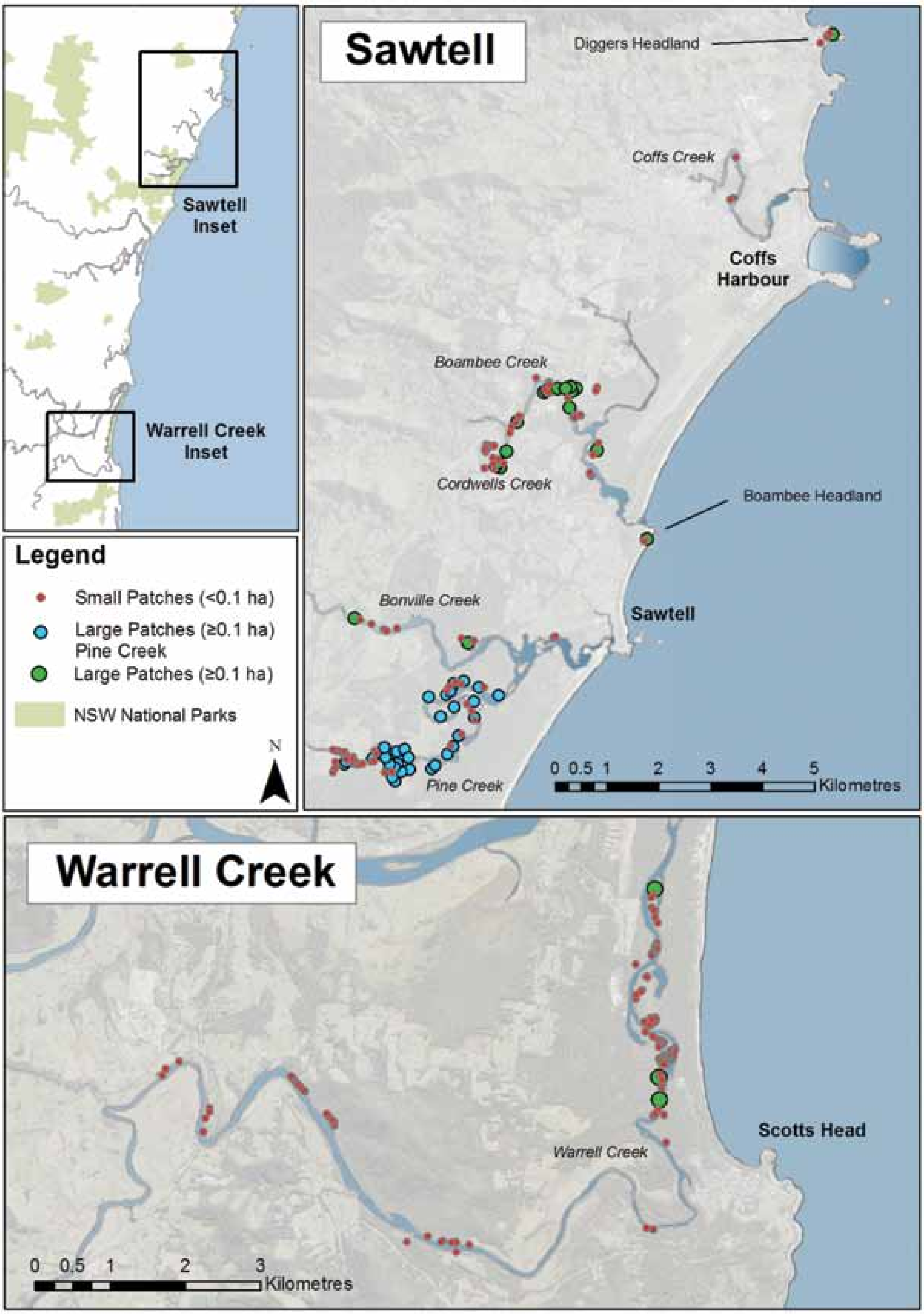
Sawtell
Inset
Warrell Creek
Inset
Legend
● Small Patches (<0.1 ha)
○ Large Patches (≥0.1 ha) Pine Creek
● Large Patches (≥0.1 ha)
🟩 NSW National Parks
N
Sawtell
Diggers Headland
Coffs Creek
Coffs
Harbour
Boambee Creek
Cordwells Creek
Boambee Headland
Bonville Creek
Sawtell
Pine Creek
0 0.5 1 2 3 4 5 Kilometres
Warrell Creek
Scotts Head
Warrell Creek
0 0.5 1 2 3 Kilometres

Figure 4. Potential *O. knightorum* habitat. The patches are very small relative to the geographic range covered; to be seen at this scale, they are denoted schematically by circular symbols.

The accuracy of the mapping was dependent on the number of satellites accessed by the GPS, the amount of time spent at a point to allow the GPS to average fixes and the degree of interference from canopy cover. Accuracy varied from 1 m to 8 m.

The majority of habitat (93%) is found in the Sawtell area within a north-south distance of 8 km and within 5 km of the coast. Due to the comprehensiveness of the field assessment across the range of the Sawtell population, there are unlikely to be many large patches not found within this area. While there is still scope for more small patches to be found, we are confident that these would not be large enough to significantly alter the pattern of the results presented here for this region.

Ten highly atypical habitat patches were mapped; 4 on the south side of Diggers Headland and 6 on the south side of Boambee Headland. These patches were growing in a very different environment on a very different substrate from that observed in other patches; soils derived from bedrock (instead of alluvial deposits) and steep southern slopes (instead of flat floodplain). Despite the different environment, the growth form of the *A. repens* appeared to be the same as that growing on the alluvial substrates. *O. knightorum* was recorded on both headlands.

Three other patches were mapped that had been planted in the Coffs Harbour Botanical Gardens on Coffs Creek (A. Floyd pers. comm. 2010). *O. knightorum* was recorded on all three small patches in the Botanical Gardens, including the smallest patch that was only 21.3 m^2 in size. High numbers were recorded, including 112 adults at one time in a patch of 172 m^2. These patches were located approximately 3 km from the Diggers Headland population to the north and 5 km from the Boambee Creek population to the south.

One patch was mapped on Bonville Creek where the NSW Roads and Traffic Authority translocated *A. repens* away from the construction of a new alignment of the Pacific Highway. It was translocated approximately 250 m east along the north bank of Bonville Creek from the new highway into typical habitat near other naturally occurring patches of *A. repens*. *O. knightorum* was recorded in this translocated habitat.

All other patches of habitat were in, or close to swamp forest. Where detailed vegetation mapping was available, it showed that most habitat fell within the Broadleaved Paperbark-Willow Bottlebrush Floodplain Swamp Sclerophyll Forest community (from the mapping of Cameron *et al.* 2011). An example of the detailed mapping is shown in Fig.5, with some of vegetation communities from Cameron *et al.* (2011) overlain.

Swamp Oak, *Casuarina glauca* and Broad-leaved Paperbark, *Melaleuca quinquenervia* were the most common overstorey species and Saw Sedge, *Gahnia clarkei*, River Lily, *Crinum pedunculatum* and *Ottochloa gracillima* commonly shared the understorey. Partial shade (dappled sunlight) at ground layer was typical of the swamp forest environment where *A. repens* occurred.

A major outcome from this study was the extension of the known range of the species south by more than 40 km to Warrell Creek near Scotts Head; 132 patches were mapped in this new southern population which is disjunct from the Sawtell population by more than 40 km. Thorough survey of 40 km of coastal catchments was beyond the scope of the current study and we consider it likely that more populations will be found in future. At present, however, Warrell Creek contains only 6% of the total known habitat area.

Across the entire extent of *O. knightorum*, patch size ranged from 1.0 m^2 to 4.18 ha. However, the number of patches is heavily skewed toward small size (Fig. 6).

A relatively small number of large patches (defined as those ≥0.1 ha) contained almost 90% of the total area. Patches were also concentrated along Pine Creek, with over 75% of the total area contained in the 80 patches along Pine Creek (Table 1).

Most (97%) of the recorded observations of *O. knightorum* were within or adjacent to patches of *A. repens*. However, in addition to the 3,208 individual adult butterflies recorded in *A. repens* patches, hundreds more were observed in passing, but for reasons of practicality not recorded. In contrast, all butterflies that were not within or adjacent to patches of *A. repens* were recorded, yet these only comprised 3% of the recorded observations. Many kilometres of potential habitat were traversed during the course of the surveys to locate *A. repens* patches. No *O. knightorum* were observed in these surveys except in regions where *A. repens* was found. On several occasions, the butterfly was observed first and then *A. repens* located nearby following a search of the area. We believe that despite these data being biased due to the focus of the surveys on areas of *A. repens*, it does provide a very strong indication that *A. repens* is crucial habitat for adult butterflies.

O. knightorum was observed within 155 of the 293 patches of *A. repens*, a patch occupancy rate of 52%. However, the occupancy of large patches (those greater than 0.1 ha) was 100%. In contrast, the species was recorded in only 14 of the smallest 100 patches. Due to the high occupancy rate in large patches, in terms of area over 97% of the *A. repens* was occupied by the butterflies.

O. knightorum was observed in all months from August to May and shared its *A. repens* habitat with the Brown Ringlet *Hypocysta metirius*, Green Grass-dart *Ocybadistes walkeri sothis*, Narrow-brand Grass-dart *Ocybadistes flavovittatus flavovittatus,* Dingy Grass-dart *Suniana lascivia lascivia*, Wide-brand Grass-dart *Suniana sunias* and Varied Sword-grass Brown *Tisiphone abeona morrisi*.

Despite the apparent fidelity to *A. repens*, it is possible that *O. knightorum* utilises other habitats to a greater extent than is currently known. They were occasionally recorded up to about 80 m from the nearest patch of *A. repens*. Other grasses in which adult *O. knightorum* were observed included patches of *Ottochloa gracillima*, *Panicum simile* and *Oplismenus imbecillis*.

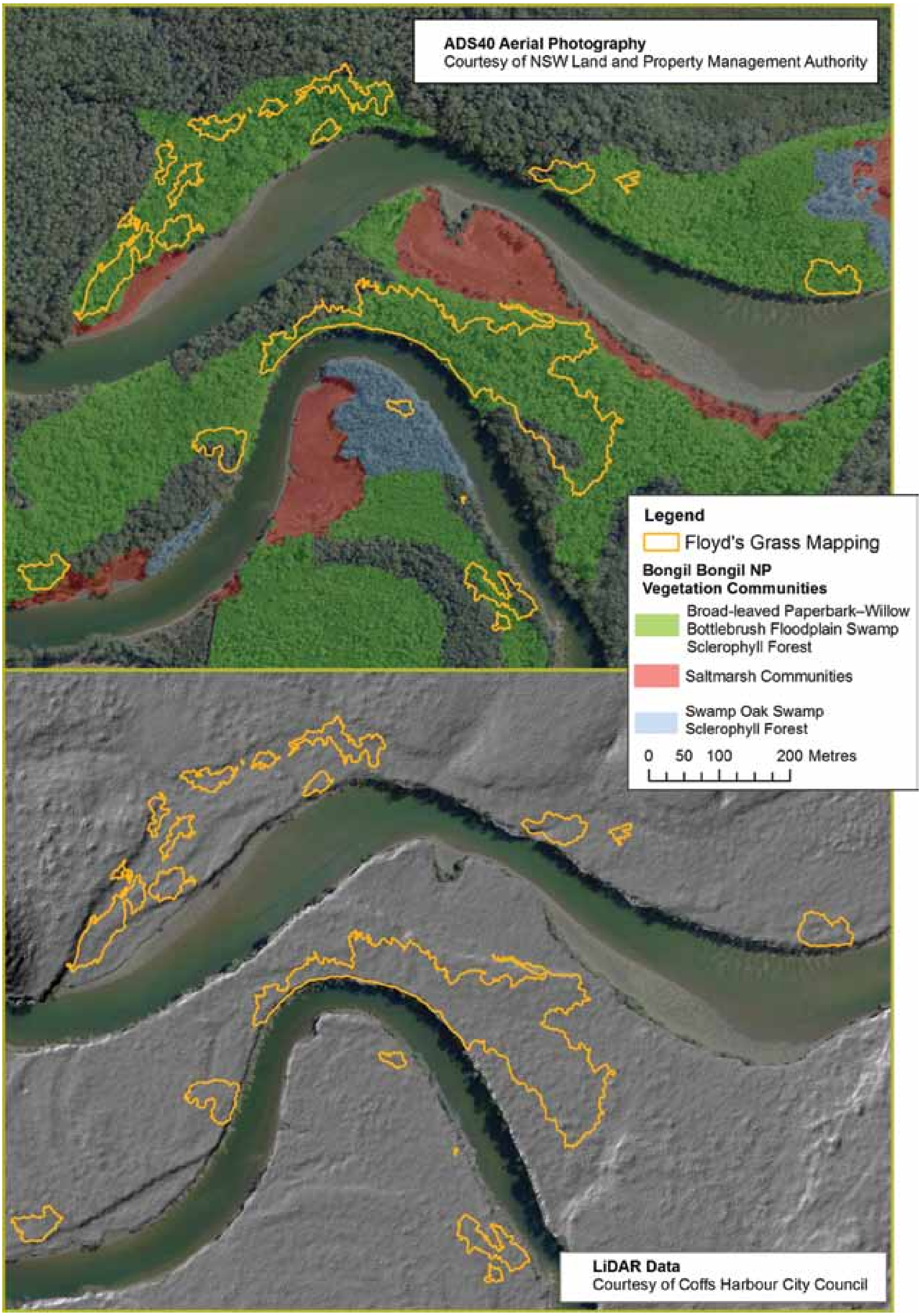
ADS40 Aerial Photography
Courtesy of NSW Land and Property Management Authority
Legend
Floyd's Grass Mapping
Bongil Bongil NP
Vegetation Communities
Broad-leaved Paperbark–Willow Bottlebrush Floodplain Swamp Sclerophyll Forest
Saltmarsh Communities
Swamp Oak Swamp Sclerophyll Forest
0 50 100 200 Metres
LiDAR Data
Courtesy of Coffs Harbour City Council

Figure 5. An example of the detailed mapping taken from Bongil Bongil National Park. The habitat was generally located above the saline communities (such as the Saltmarsh and Swamp Oak Swamp Sclerophyll communities shown) and within the Broadleaved Paperbark-Willow Bottlebrush Floodplain Swamp Sclerophyll Forest community. Vegetation communities from Cameron *et al.* (2011).

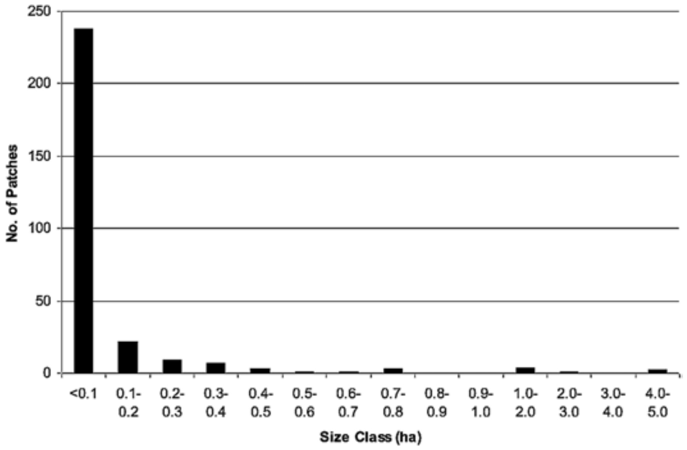

Figure 6. The size class distribution of 293 patches of known and potential *O. knightorum* habitat, highlighting the predominance of small-sized patches.

Table 1. *O. knightorum* habitat classified by size and location. The 35 large patches on Pine Creek are clearly critical to the conservation of the species.

Category	No. of patches (% of total)	Area in hectares (% of total)
Large patches (>0.1ha) along Pine Creek	35 (12)	23.47 (72)
Other large patches (>0.1ha)	21 (7)	5.48 (17)
Small Patches (<0.1ha)	237 (81)	3.49 (11)

The distribution of habitat according to tenure and Local Environmental Plan (LEP) 2000 Zones for Coffs Harbour City Council (CHCC 2000) and Nambucca Valley Shire Council (NVSC 2010) is shown in Table 2. Most of the habitat in NPWS reserves is located in Bongil Bongil National Park (95%), with some small areas in Gaagal Wanggaan National Park (3.5%) and Coffs Coast Regional Park (1.5%). Since parts of these reserves have been declared since the Coffs Harbour City Council LEP was reviewed in 2000, all areas have been assigned LEP Zone 8 (National Park) regardless of the older zonings. Parcels of Crown Land that contain habitat are managed by five government bodies: Coffs Harbour City Council, NSW Lands and Property Management Authority, NSW Department of Transport, Southern Cross University and the NSW Department of Education and Training.

Discussion

The habitat of few, if any, Australian butterfly species has been surveyed and mapped as comprehensively and in as detailed a fashion as that presented here for *O. knightorum*.

We are confident that the patches of the food plant, *A. repens*, are of key importance to the adult as well as the larval stage of *O. knightorum*. There were few observations of adult butterflies greater than about 20 m from any *A. repens* patch despite the many

Table 2. The tenure of known and potential *O. knightorum* habitat in the local government areas of Coffs Harbour City Council (CHCC) and Nambucca Shire Council (NSC).

LEP[a] Zone	NPWS[b] Reserves (ha)	Crown Land (ha)	Freehold (ha)	Total (ha)	(% Grand Total)
CHCC[c]					
1A			0.03	0.03	(0.1)
2A		0.01	0.04	0.05	(0.2)
4A			0.24	0.24	(0.7)
5A		0.34	0.02	0.36	(1.1)
6A		1.40		1.40	(4.3)
7A		0.17	11.47	11.64	(36)
8	16.81			16.81	(52)
NSC[d]					
RE1		0.09		0.09	(0.3)
RU1			0.58	0.58	(1.8)
RU2			0.17	0.17	(0.5)
E1	0.63			0.63	(1.9)
E2			0.45	0.45	(1.4)
Total (ha) (% Grand Total)	17.44 (54)	2.01 (6)	13.00 (40)	32.45	

[a] Local Environmental Plan

[b] NSW National Parks and Wildlife Service

[c] CHCC Local Environmental Plan 2000: 1A (Agriculture), 2A (Residential low density), 4A (Industrial), 5A (Special purposes), 6A (Open space public recreation), 7A (Environmental protection), 8 (National Park)

[d] NSC Local Environmental Plan 2010: RE1 (Public recreation), RU1 (Primary production), RU2 (Rural landscape), E1 (National park), E2 (Environmental conservation).

hours spent searching kilometres of other potential habitat. In contrast, more than 3,000 individual adult butterflies were recorded in patches, or within 20 m of patches. We therefore feel justified in focussing this study on the *A. repens* patches, all of which were considered to be potential habitat of the butterfly.

Adult *O. knightorum* were observed consistently from September to March, small numbers recorded in April, early May and late August, and none from late May to early August. For many butterfly species, numbers are known to fluctuate widely and the number of adults present at any time is dependent on the success of each stage in the life cycle (Sands and New 2002). This uncertainty, combined with the lack of detailed knowledge of the biology of the butterfly, confounds the interpretation of observed adult numbers. We can therefore say little at this stage about the population size of *O. knightorum* or, for example, what would constitute a viable population.

According to the mapping of Troedson *et al.* (2004), most *O. knightorum* habitat occurs on Holocene alluvial deposits. These were generally rich in organic matter and supported vigorous examples of *A. repens*. Where *A. repens* occurred on saline, inundated or poorer quality bedrock environments, its growth was less vigorous and potentially of lower habitat quality to the butterfly (M. Andren pers. obs. 2011). *A. repens* was also observed to be less vigorous in conditions of low light penetration that occurred where it was growing in vegetation communities with greater canopy cover than swamp sclerophyll forest (such as rainforest or shrubland). While all these occurrences may be part of the natural dynamic of *A. repens* at the margins of its tolerance, many of them represent poor quality habitat that is unlikely to deliver significant conservation returns from rehabilitation efforts.

Many habitat patches were threatened by introduced weeds, particularly the most prevalent species - Lantana, *Lantana camara* and Broad-leaved Paspalum, *Paspalum madiocanum*. *L. camara* develops dense thickets that shade and eventually eliminate *A. repens*, while *P. madiocanum* forms a dense root mat that excludes most other plant species from surviving within its root zone. Anecdotal observations suggest that both weed species appear to invade habitat patches readily (M. Smith pers. comm. 2010, M. Andren pers. obs. 2011). Where weeds had been removed, *A. repens* responded rapidly with vigorous growth (M. Andren pers. obs.). However, it is extremely unlikely that sufficient resources would ever be available to remove weeds from, and then maintain, all 293 patches.

The mapped habitat was very low-lying, apart from the atypical headland populations that were at higher elevation. Most of the habitat was below 2 m above mean tide-line. Since there is predicted to be a rise in sea level on the north coast of 0.9 m above the 1990 level by 2100 (DECCW 2009), much of this habitat is under direct threat from this dimension of climate change.

It was also observed during the surveys that in some areas there was a significant threat posed by anthropogenic disturbance. Visible disturbance included the creation of trails for walking, bike riding and off-road driving, as well as the dumping of waste. It was most severe in the most urbanised catchment (Boambee Creek) and had the secondary effect of facilitating weed invasion. The Boambee and Bonville Creek catchments have been subject to rapid urbanisation over the last 30 years and this is planned to continue throughout the next 30 years (CHCC 2008). The impact of direct and indirect disturbance in these catchments will be greatly exacerbated and poses a serious threat to the size and quality of the habitat in these catchments. There was much less visible anthropogenic disturbance in NPWS reserves, where access is restricted under the conservation-oriented management.

O. knightorum habitat appears to be intrinsically patchy. Even prior to European settlement, areas of swamp forest on rich alluvial substrates suitable for *A. repens* would likely have been patchily distributed along the meandering lower reaches of watercourses. While the clearing of swamp forest in places is likely to have fragmented some areas of previously contiguous habitat, it is also likely that the butterfly always had to cope with patchily distributed resources.

O. knightorum was confirmed to occupy 69 of the largest 70 patches, including all large patches (□0.1ha). Large patches along one 7 km stretch of Pine Creek form the core of the known habitat, containing 72% of the total area. These large patches on Pine Creek are likely to be a major source for patch re-colonisation and critical for the conservation of the species. Large patches located in other areas contain a further 17% of the total area and could also play an important role in harbouring potential "insurance" populations.

Most of the patches (237 of them, or 81%) were small, i.e. <0.1 ha in size. Despite the large number, these small patches contributed only 3.5 ha (11%) to the total habitat area. *O. knightorum* was often not found in small patches; none were observed in nearly 60% of them, including 86 of the smallest 100 patches. In very small patches (less than 10.0 m^2) the butterflies were absent altogether.

There are several possible explanations for the absence of butterflies from small patches. They generally contain fewer butterflies than large patches, so the chance that no adult stage was present at the time of sampling is much higher for small patches. Stochastic extinction within small patches may also be a regular occurrence within a broader metapopulation; recolonisation from source habitat may occur at a later date.

Small patches may simply be too small, isolated or lacking in quality to support *O. knightorum*. However, butterflies can exhibit surprisingly large distance dispersal (Baguette 2003) and *O. knightorum* was observed across the full range of the distribution of *A. repens*. This included many small and isolated patches.

It was found in eight very small and apparently isolated patches at Warrell Creek (averaging 107.0 m^2), in all three of the very small patches in the Coffs Harbour Botanic Gardens (averaging 84.6 m^2) and on Diggers Headland (which is more than 8 km from the next nearest naturally-occurring population). Consequently, the temporary absence of butterflies, even from small and remote habitat patches, should not be taken as an indication that the patch plays no part in the dynamics of the metapopulation over a longer time period.

Despite the emphasis placed here on the *A. repens* habitat patches, the resources in the surrounding matrix are likely to be important (Ricketts 2001). Within about 20 m of a patch, adult butterflies make regular use of the shelter, nectar and perching resources available. The matrix is also critical during dispersal. Corridors have been found to be used by some butterflies (Baguette *et al.* 2000; Haddad 1999; Haddad and Baum 1999; Hill 1995; Vandewoestijne *et al.* 2004), particularly if they supply resources such as food and shelter that dispersing adults require. Grassy forest or woodland corridors may assist the dispersal of *O. knightorum*. It has also been observed in open grassy paddocks with scattered trees (M. Andren pers. obs. 2010). Areas of relatively open derived grassland may therefore not present a major barrier to dispersal. However, urban expanses may be difficult for such a small species to permeate, given the need for long flights across unsuitable habitat. We believe that the rapid urbanisation of the Sawtell hinterland could lead to reduced connectivity between the Boambee Creek catchment population and that in the Bonville Creek catchment.

Habitat fragmentation is therefore an ongoing threat to the conservation of *O. knightorum*. However, since the species has probably always had to cope with patchily distributed resources, then the loss of habitat quality may be the greater threat. Preventing further attrition of quality would be extremely costly, e.g. defending the 237 small patches against threats such as weed invasion or disturbance. There is also the potential for inbreeding depression caused by infrequent recruitment in small and isolated patches, and many of these patches are not high quality as they are located in marginal environments. Since protecting all the small patches would result in only 3 ha of habitat protected, we consider that this would be ineffective as a conservation strategy, given the limited resources available. In contrast, large patches offer the opportunity to protect most of the habitat area at a relatively small cost per hectare. We recommend that the large (□0.1 ha) patches identified in this study should be the initial focus of rehabilitation actions for the species.

The level of protection of *O. knightorum* habitat is relatively high when compared to many other species. NPWS reserves contain 17.4 ha (54%) of the mapped habitat, including 15 of the 25 largest patches and the northern and eastern range limits. These 15 large patches occur in Bongil Bongil National Park, which contains 53% of the total habitat area. An objective of the Bongil Bongil National Park Plan of Management is to maintain the habitat of the species (NPWS 1999). Although under-resourced, conservation management actions have been implemented, including weeding, the suppression of unscheduled fire and the control of access. It is apparent that the butterfly is a major beneficiary of the targeted conservation management occurring in this reserve, especially when compared with the apparent lack of action on most other tenures.

An additional 12.1 ha (37%) of *O. knightorum* habitat is within environmental protection zones applied by local government. When combined with the 54% in reserves, a total of 91% of the habitat has some level of protection. This includes most of the large (□0.1 ha) patches identified in this study. However, 10 of the large patches (comprising 1.3 ha) fall wholly or partly outside this protection and we recommend that these should also be fully protected.

The results presented here show that the habitat of *O. knightorum* is much more extensive than assumed at the time the species was listed as endangered, and also that the habitat is relatively highly protected. However, there remain significant threats to the species, some of which are operating independently of tenure such as sea-level rise and weed invasion. Further investigation of these threats is needed to adequately reassess the conservation status of the species.

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